Gas Well Production Optimization

User Manual

For Emerson FloBoss and ROC RTU

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Revision History

Revision	Author	Date	Comments
1.00	J.S	2009-04-27	Original Release

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Table of Contents

INTRODUCTION **8**

INSTALLING THE PROGRAM **9**

VIEWING USER PROGRAM SCREENS 10

CONFIGURING THE RTU **11**

ROC INFORMATION 11
PID SETTINGS 12
DO SETTINGS 13
I/O SETUP 14

CONFIGURING THE PROGRAM **15**

PROGRAM AUTHORIZATION 15
PARAMETERS ASSIGNMENT 17

OPERATION **18**

TYPICAL WELL CHARACTERISTICS 18
PROGRAM CHARACTERISTICS 19
MODE 1 (TIME ON VS. TIME OFF) 20
MODE 2 (CRITICAL FLOW VS. TIME OFF) 22
MODES 3 & 4 (CRITICAL FLOW VS. CASING / STATIC DIFFERENTIAL PRESSURE) 24
MODE 5 (CASING STATIC DIFFERENTIAL PRESSURE VS. TIME OFF) 26
MODE 6 (CRITICAL FLOW VS. CASING PRESSURE) 28
MODE 7 (CRITICAL FLOW VS. LOAD FACTOR < SET POINT) 30
MODE 8 (SELF OPTIMIZATION) 32
MODE 8 - SELF OPTIMIZATION SUPPLEMENTARY INFORMATION 33

APPENDIX A – AVAILABLE CONTROL MODES **36**

APPENDIX B – GLOSSARY **40**

APPENDIX C – PARAMETER DEFINITION AND INITIALIZATION **41**

APPENDIX D – TROUBLESHOOTING **43**

APPENDIX E – PLUNGER SENSOR WIRING & VELOCITY CALCULATIONS **45**

APPENDIX F – CONTINUOUS CRITICAL FLOW CALCULATION (GRAY EQUATION) **46**

APPENDIX G – DATA SAMPLE OPTION ..... ERROR! BOOKMARK NOT DEFINED.

APPENDIX H – ROCLINK 800 USER DISPLAY FILE **47**

REFERENCE **48**

Table of Figures

Figure 1 - User Program Administrator Screen 9
Figure 2 - ROCLINK 800 Main Screen 10
Figure 3 - Unit Standard Configuration 11
Figure 4 - PID Control Enable 11
Figure 5 - Sample PID Screen 12
Figure 6 - Sample DO Screen 13
Figure 7 - Sample I/O Setup Screen 14
Figure 8 - Program Authorization 15
Figure 9 - Outlaw Automation Secured Customer Login Page 16
Figure 10 - Optimization Program Authorization Code Generation Page 16
Figure 11 - Optimization Program Authorization Code Input Page 17
Figure 12 - Example Well Flow Cycle 18
Figure 13 - Mode 1 Configuration 21
Figure 14 - Mode 2 Configuration 23
Figure 15 - Mode 3/4 Configuration 25
Figure 16 - Mode 5 Configuration 27
Figure 17 - Mode 6 Configuration 29
Figure 18 - Mode 7 Configuration 31
Figure 19 - Mode 8 Correction Factor Logic 34
Figure 20 - Mode 8 Configuration 35
Figure 21 - Plunger State Diagram 38
Figure 22 - Program Operation 39

List of Tables

Table 1 Start Position Settings 21
Table 2 - PID and AGA Controls 36
Table 3 - Control Modes Summary 36
Table 4 - Control Modes - Hardware Requirements 36
Table 5 - Parameter Definition and Initialization 41
Table 6 - Troubleshooting List 43
Table 7 - Error Code List 43
Table 8 - Mode Status Code List 44
Table 9 - Critical Flow Calculation Units 46

Introduction

This document provides an overall guidance for the installation and Configuration of the Outlaw Automation Inc. (OAI) Gas Well Production Optimization Program for Emerson Fisher RTUs.

The current version of the program supports the following RTU Types:

1. ROC 300 Series RTU(306/312/364) with FLASHPAC
2. ROC 300 Series RTU(306/312/364) with ROCPAC
3. FloBoss 407 RTU
4. FloBoss 103 RTU
5. FloBoss 107 RTU

The program offers 8 different control modes targeted to maintain, or increase in gas production. Depending on the mode selected, control functions utilize timers, gas flow rate, well pressure, plunger arrival data or a combination thereof.

The Time On/Off and Plunger Control - Fixed Timers modes are the only selections that will result in definite well on and off times. All other modes will result in a variable on time, a variable off time, or both variables on and off times. Times will vary based on the characteristics of the well and the entered set points.

Please note that all screen captures or diagrams are based on FloBoss 107 RTU configuration. Unless notified, all supported RTUs will follow the same installation and configuration procedures.

WARNING

This program is specifically designed to take over operation of well control functions to produce the desired production optimization effects. Although safety features are built into the program to prevent dangerous situations from occurring, once the optimization program is active it is up to the operator to be aware of the results of selecting an optimization mode or changing setpoints.

Installing the User Program

A computer with ROCLINK 800 Version **1.73** or later and a serial communication port is required. The computer must be connected to the RTU Local Operator Interface (LOI) port and must be On-Line (from the ***ROC*** menu choose ***Direct Connect***).

From the ***Utilities*** menu choose ***User Program Administrator***, and click on the ***Browse*** button to locate the **BIN** file to be downloaded to the RTU.

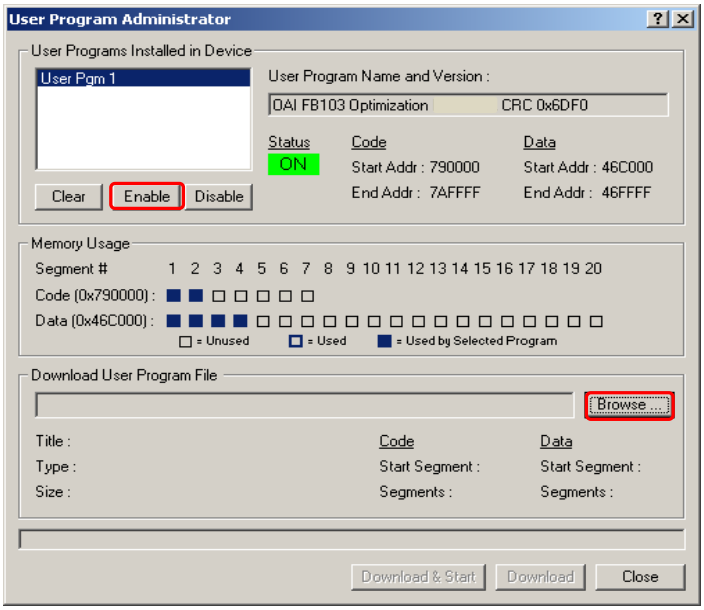

Figure 1 - User Program Administrator Screen

Select the appropriate **.BIN** file and then click on the ***Open*** button. Click on the ***Download*** button and then click on the ***Yes*** button to confirm the download. The status bar and message at the bottom of the window will indicate the progress of the download. When completed, the top section of the window will display the User Program Name and Version as well as memory usage information.

Clicking on the ***Enable*** button enables the program run flags and performs a **Warm Start**. The program Status will change from ***OFF*** to ***ON***.

To ensure that the program starts automatically after a Cold Start, perform a ***Save to Flash Memory*** in the ***ROC->Flags*** menu. Please refer to the ***ROCLINK 800 Configuration Software User Manual*** for more information.

Click on the ***Close*** button to exit the User Program Administrator.

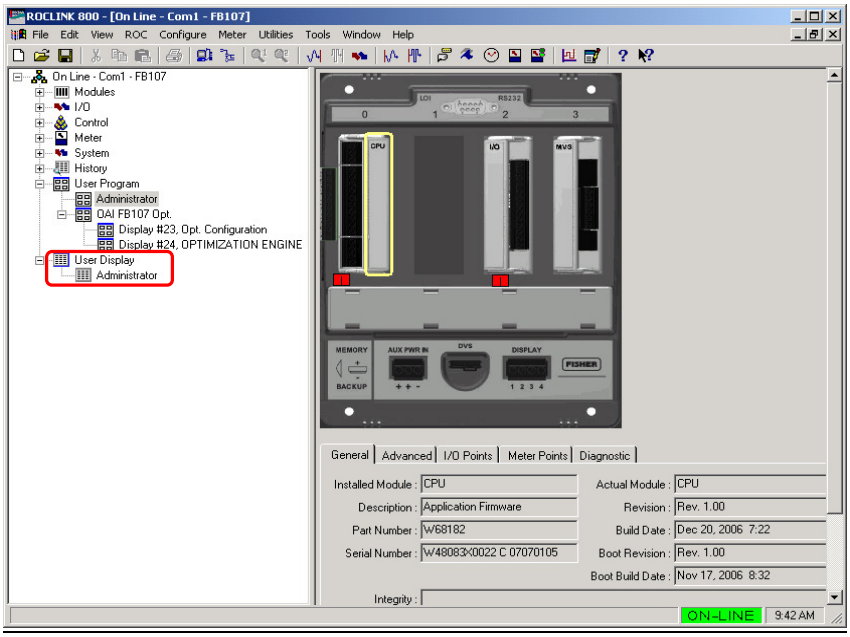

Figure 2 - ROCLINK 800 Main Screen

Expand the ***User Program*** and ***User Data*** menus. Double-click on ***Administrator*** to return to the User Program Administrator window.

Viewing User Program Screens

Expand the ***User Display***, Double-click on ***Administrator*** to load or open customized display interface. All optimization modes can be monitored and controlled through single display. Please see Configuring the User Program for details.

Configuring the RTU

Certain control functions and I/O assignments must be configured in the RTU for the OAI user program to function correctly.

- The PID loop **MUST** be Active and enabled *or* a Digital Output device **MUST** be installed.
- The AGA calculation **MUST** be active.
- Scanning of auxiliary I/O points **MUST** be enabled for some control modes to function correctly.

ROC Information

Units may be set as US or Metric. The ONLY way to switch Unit Standard is through ROCLINK 800. Go to ***ROC*** menu -> ***Information***, select the US or Metric unit as needed.

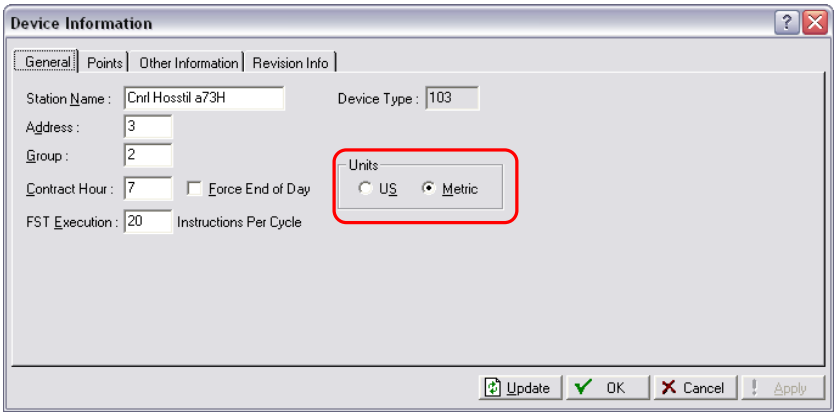

Figure 3 - Unit Standard Configuration

The factory default setting ***Disables*** the PID loop. If the PID is used for control then choose ***ROC*** menu -> ***Information*** and click on the ***Points*** tab. Enter a non-zero number in the ***Active PID*** field and click on ***Apply***. The number of Active AGAs determines how many flow run calculations are active. Please see Appendix A Table 2 PID and AGA Controls for detail.

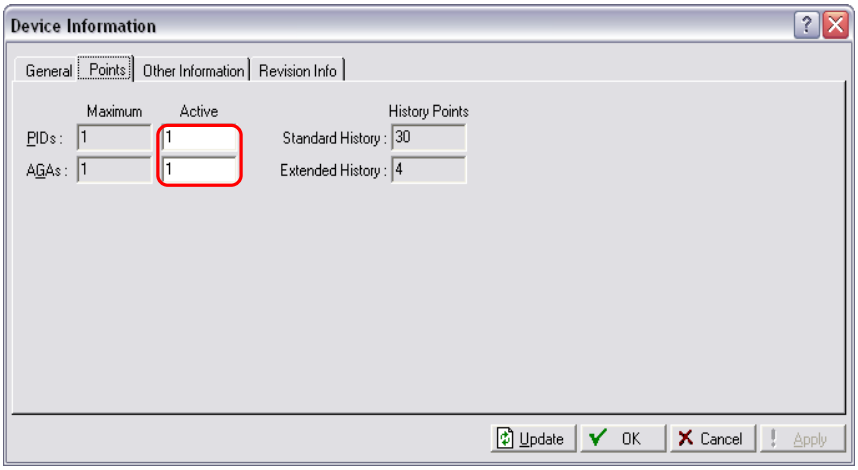

Figure 4 - PID Control Enable

PID Settings

PID loop configuration is required if an **Analog Output** type of control valve is used.

Go to menu ***Configure*** -> ***Control*** -> ***PID Loop***:

1. Set Control Type to Primary Only (please consult with Outlaw Automation if Override Control Loop is required)
2. Set Output Type to Analog
3. Set Scanning to Enabled
4. Set Mode to Auto
5. Set Primary Output Point to the desired AO point
6. Set Primary Set Point Value. A large value will open the controlled valve more quickly.

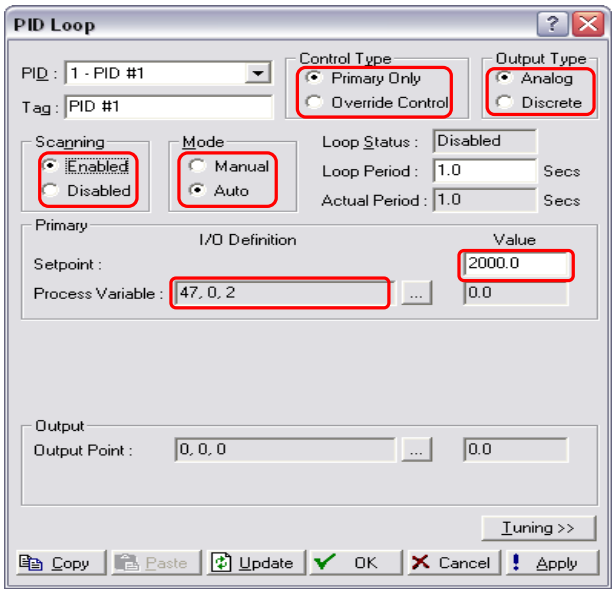

Figure 5 - Sample PID Screen

DO Settings

DO point configuration is required if a **Discrete Output** type of control valve is used.

Go to menu ***Configure*** -> ***I/O*** -> ***DO Points***:

1. Select correct DO point
2. Set DOUT Type to Latched
3. Set Scanning to Enabled

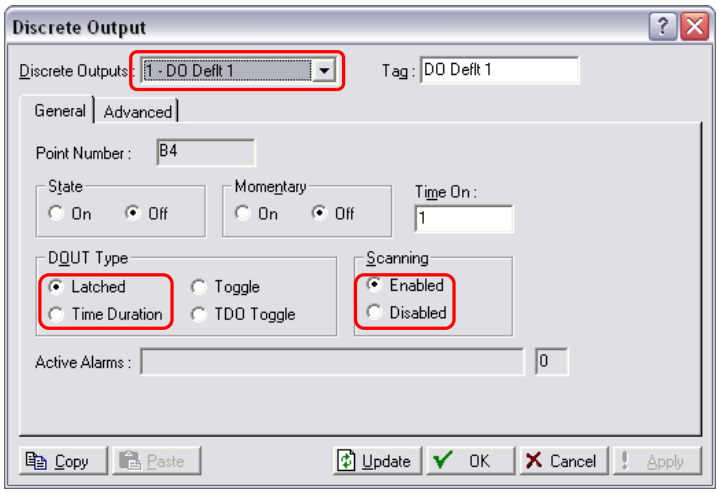

Figure 6 - Sample DO Screen

I/O Setup

If a plunger arrival sensor is connected to a DI point then that DI point must have its ***DIN Type*** set to ***Standard*** and the ***Plunger Sensor*** TLP on the ***User Display*** screen must be defined as that DI point.

If a plunger arrival sensor is connected to a PI point then the ***Plunger Sensor*** TLP on the ***User Display*** screen **MUST** be defined as that PI point.

The output type (Discrete or Analog) **MUST** be consistent through the ***I/O Setup*** and PID ***Output Point*** and ***Output Type*** configuration if PID control is used.

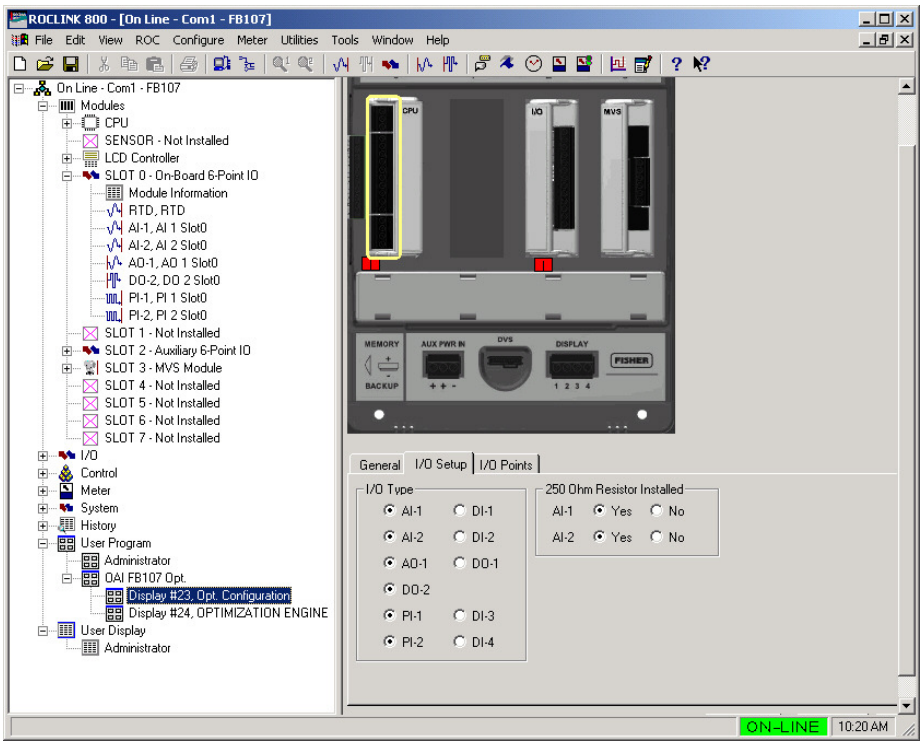

Figure 7 - Sample I/O Setup Screen

Refer to the ***RTU Instruction Manual*** [ii] for more information on the configuration of I/O module.

Configuring the User Program

Configuration of the Optimization Program consists of several steps:

- Entering the PIN code to authorize the program.
- Assigning ROC information in the form of a TLP to the program parameters.
- Entering Setpoints for timers and process variables.
- Managing Soft Points to store the data calculated by the program (Optional).

Refer to Section 5 – Operation for detailed information on the configuration of each control mode.

Program Authorization

From ROCLINK 800, open the ***User Display*** screen. Record the two five digit numbers ***PIN #1*** and ***PIN #2*** found at the ***Right Bottom*** of the ***User Display*** screen.

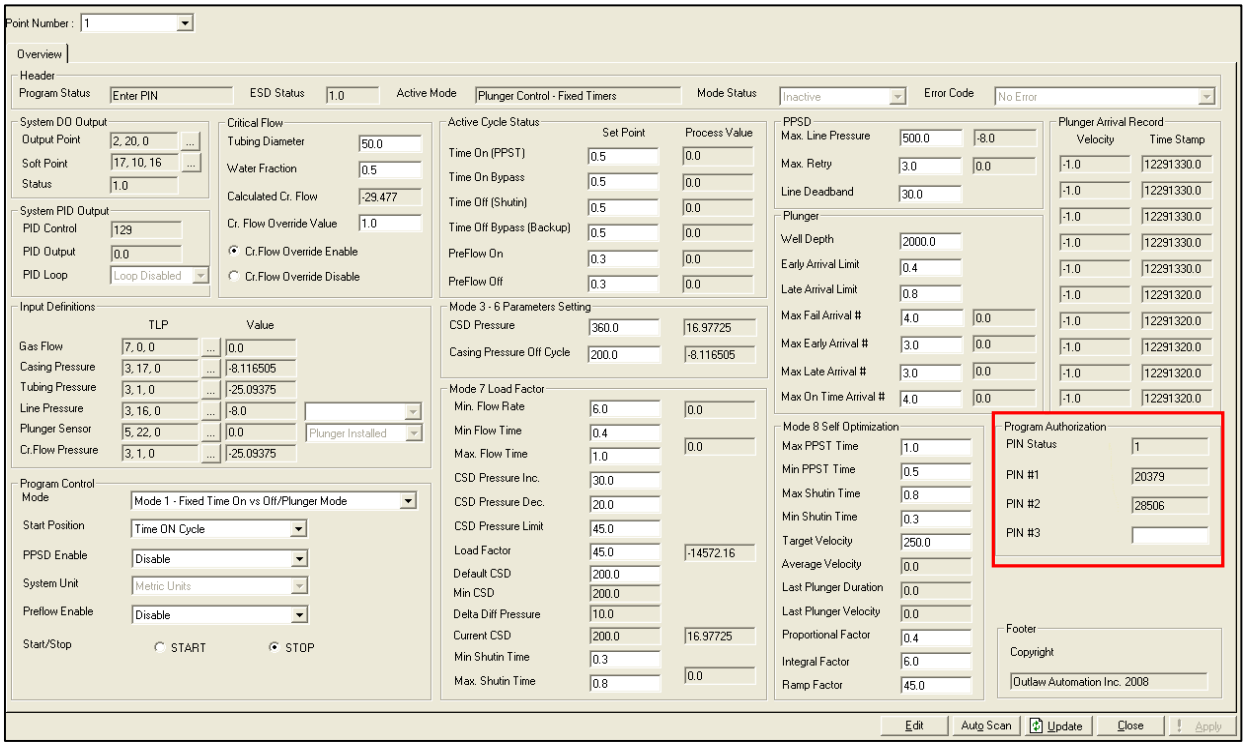

Figure 8 - Program Authorization

Go to www.outlaw.ca and click on the ***Optimization Key Generator*** link at the **Bottom Right** hand side of the screen for a code request. A security login (Figure 9) with ***Company*** name***, User*** name, and ***Password*** is required to continue. To obtain the Security login information or program authorization code contact Outlaw Automation toll free ***1-866-408-5001*** or ***1-403-253-5001***. Please be sure to specify the number of meter runs required for optimization when setting up the account.

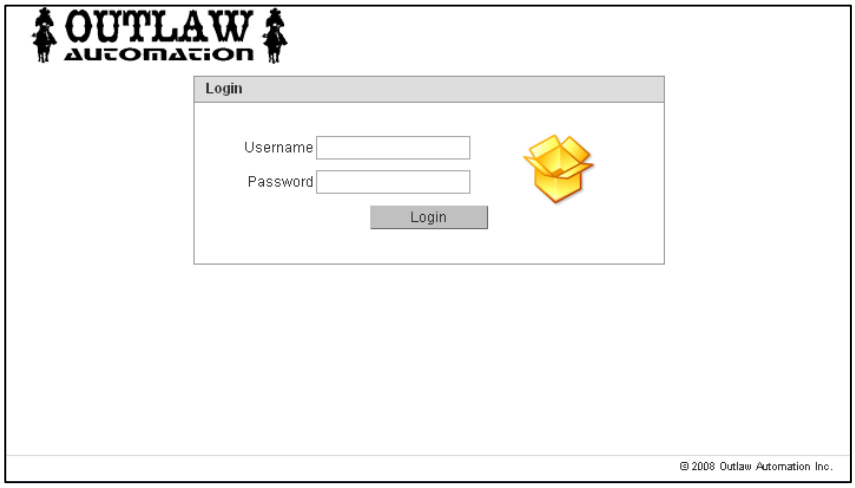

Figure 9 - Outlaw Automation Secured Customer Login Page

After logging into Code Generation Page (Figure 10), ***Select*** the destination area, then click to add new authorization key.

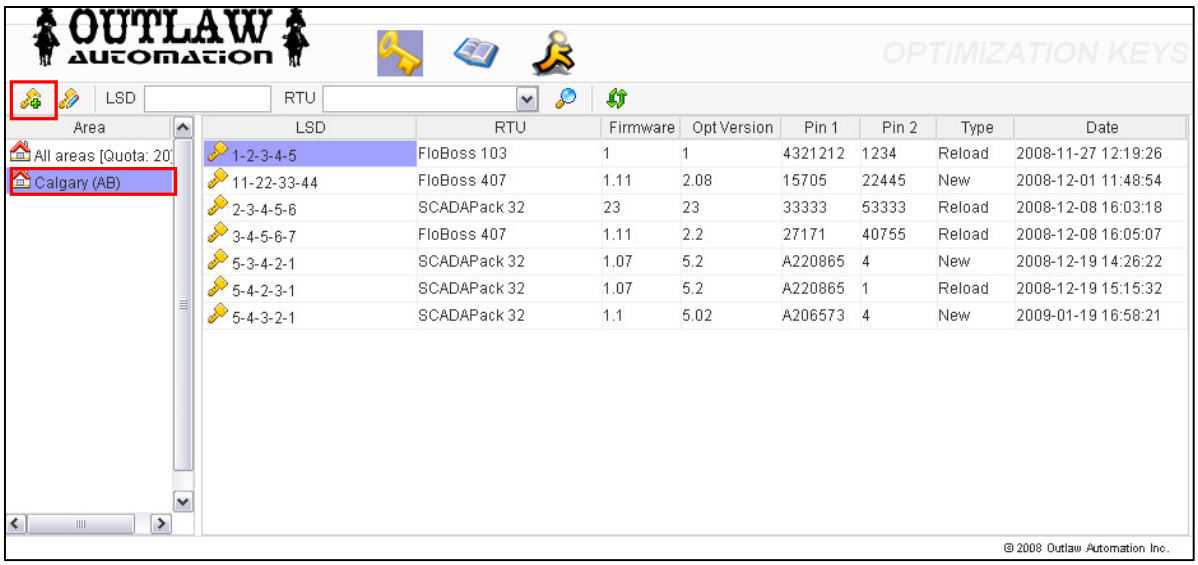

Figure 10 - Optimization Program Authorization Code Generation Page

In the Key Input Page (Figure 11), ***Fill In*** all the blanks and ***Select*** correct RTU type and Operation. Click ***Submit*** button, an authorization code will appear in the ***Code*** box for ***PIN 3***. If a valid Email address is provided as part of the billing information, a complete record of the code generation will be sent to that address. This authorization code should be either printed or written down for future reference.

Enter the authorization code in the ***PIN 3*** of ***User Display*** screen (Figure 8) and click ***Apply*** then ***Update***. The ***Active Mode*** message will update from ***Initialization Complete; Enter Pin*** to ***Select Optimization Mode***. The ***Program Status*** message will update from ***Enter PIN*** to ***Inactive***. If the messages do not change as described then an incorrect authorization code has been entered and the program will not run.

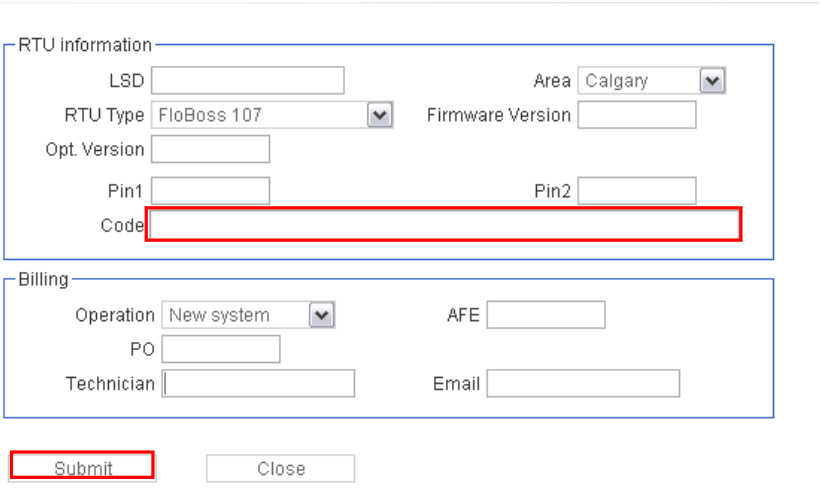

Figure 11 - Optimization Program Authorization Code Input Page

Parameters Assignment

Most of parameters on user display are associated with soft points. All parameters will be initialized to default value upon user program installation. ***Please confirm all setpoints are assigned with correct values before starting user program.***

Customers who require a special soft point mapping list should contact Outlaw Automation for assistance.

For information on ROC TLP address, please use ***ROC PROTOCOL USER MANUAL***[iii] as reference
For current available soft point definition, please refer to ***Appendix C – Parameter Definition and Initialization***.

For default soft point mapping list, please refer to ***OAI Gas Well Production Optimization Program Register list (for Fisher RTU)***[iv]

Operation Mode

Typical Well Characteristics

The figure below shows an example of Gas Flow Rate vs. Time for a typical gas well that has been shut in for a period of time, and then opened to flow. Pressure has built up during the shut-in period and the well is able to generate a high initial flow rate as the gas starts to flow out of the tubing string. There is sufficient flow to maintain a slug of liquid and bring it to the surface, or a plunger if it has been installed. The Gas Flow Rate drops significantly as the slug of liquid arrives at the wellhead and recovers once the liquid has passed or the plunger has arrived. The Gas Flow Rate will then slowly decline as pressure drops or the well begins to load. The well is shut in when the flow drops below the Critical Flow Set point.

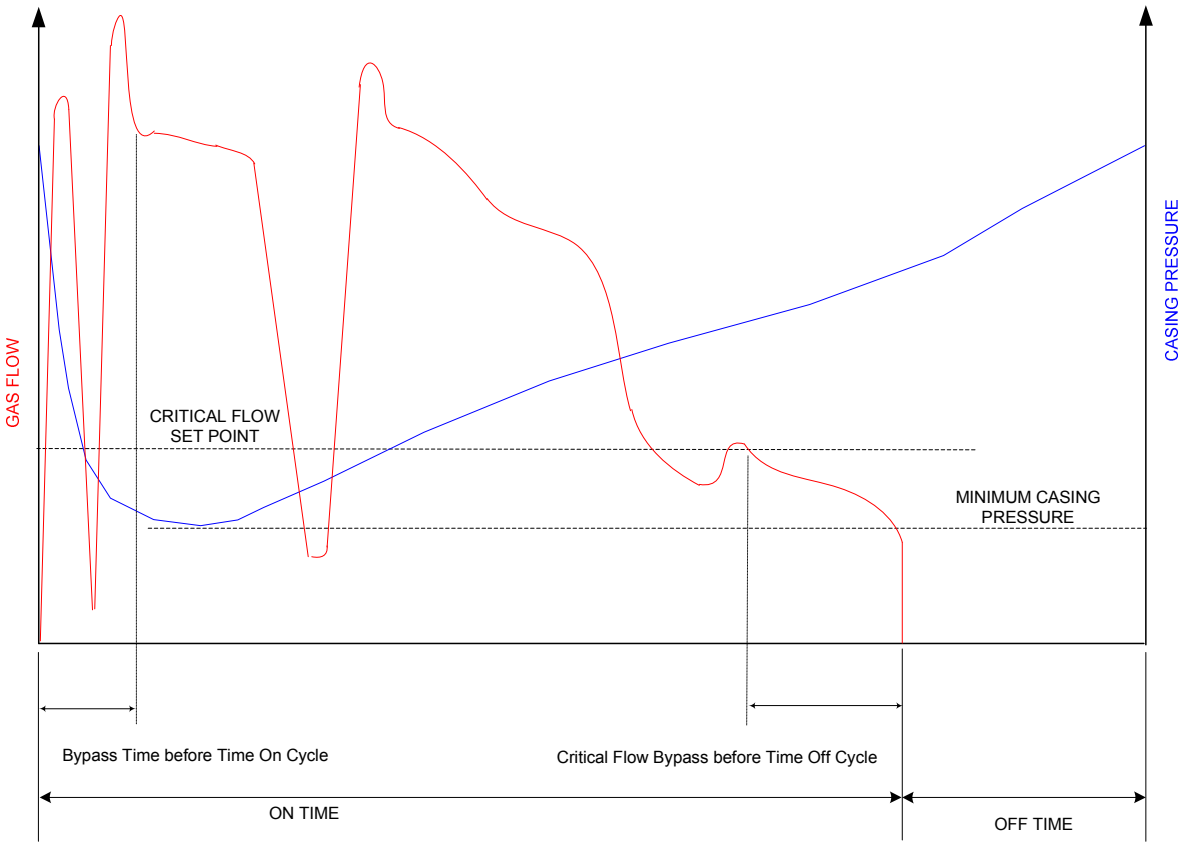

Figure 12 - Example Well Flow Cycle

When in Critical Flow mode the Critical Flow setpoint will determine the length of time that the gas well will stay open after the well unloaded. If Plunger Arrival is being monitored then the **Post Plunger Sales Time (PPST)** preset will determine the length of time that the well will stay open after the plunger arrives.

The **Time On Bypass Time** should be set at a value slightly greater than that required for unloading of liquids and/or should allow enough time for the plunger to arrive. A short **Time On Bypass Time** may result in premature shut-in of the well.

Program Characteristics

The Emergency Shut Down (ESD) logic, if purchased as an option, is written into the optimization program and will operate without the optimization program authorization code.

The optimization control may not be started if an ESD condition exists.

If an ESD condition occurs in an **Off Cycle** then the program operation will continue as usual. If the ESD condition persists at the end of the off cycle the program will hold at the start of the on cycle.

If an ESD condition occurs in an **On Cycle** then the program will hold until the condition is cleared and the ESD bypass timer has expired if ESD logic is built-in.

The program can be re-started if the fast plunger incident is a false alarm or problem has been corrected. The number of early plunger arrivals will be reset to 0 afterwards.

Plunger trip duration and timestamp are logged for the most recent ten records.

Failed plunger arrival is indicated by a value of -1 for the time of the duration.

Mode 1 (Time On vs. Time Off)

Intended Use:

- Basic On/Off control with no requirement for additional inputs (Well pressure or Plunger sensor).
- Basic On/Off control with a plunger and plunger arrival sensor. Monitoring plunger arrival allows for extended flow time if the plunger arrives, or a longer shut in time if the plunger does not arrive.

This mode provides automatic On/Off control of well flow using timer setpoints entered by operator. The cycle may be started in either the On or Off time cycle. The Time On counter will start when the program is activated if the ***Start*** flag is set to one.

For details on Plunger State Diagram, please refer to Appendix A Figure 28

- Once setpoints have been entered type a 1 in ***Start/Stop*** on the ***User Display*** screen and click ***Apply***.
- The most recent 10 plunger velocity and arrival time stamp are available on ***User Display*** if plunger sensor is installed.
- Changing timer setpoints when the timer is counting will have no effect until the next cycle.
- To force setpoint changes to take effect immediately ***Stop*** and then ***Start*** the mode.

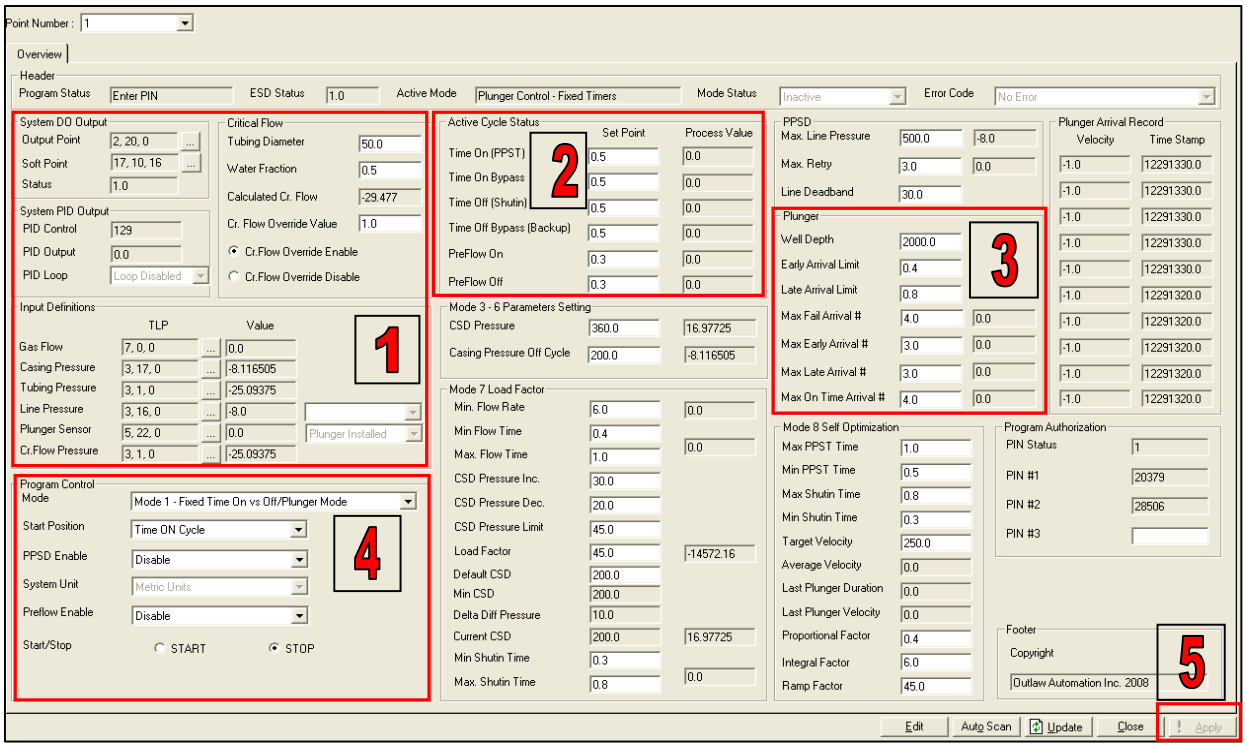

Figure 13 - Mode 1 Configuration

The minimum required configuration on the ***User Display*** screen (following Letter Number on Figure 13):

- STEP 1 – Confirm all ***System Input /Output*** Parameters has been probably setup or initialized.
- STEP 2 – Confirm ***Time ON***, ***Time Off*** setpoint value has been entered correctly.
- STEP 3 – If plunger sensor is installed, all plunger parameter set points ***MUST*** be initialized or corrected.
- STEP 3 – Confirm program is currently on ***Mode 1***.
- STEP 4 – Select ***START*** and click ***Apply*** button to start optimization program.

Table 1 - Start Position Settings

Start Flag Value	Mode 1 Initial State
0 (Default)	On Cycle If Flow Rate > 0 and PID is in AUTO Off Cycle if Flow rate = 0 or PID is in MANUAL
1	On Cycle
2	Off Cycle

Mode 2 (Critical Flow vs. Time Off)

Intended Use:
Basic On / Off control with no requirement for additional inputs (Casing pressure or Plunger sensor). Use of Critical Flow allows the on time to vary according to the well's ability to produce gas.

This mode provides automatic On/Off control based on a critical flow set point and a fixed time off period. The amount of time that the valve will be open will vary depending on the characteristics of the well. Plunger is optional with this mode. The cycle is started in the on or off time according to the Start Position.

The Minimum On Time Before Critical Flow Timer (***MOTBCF*** Timer) will begin counting down at the start of the on cycle. The purpose of this timer is to permit flow for a minimum period of time before checking flow rate, and if a plunger is installed, to allow enough time for the plunger to arrive. Once the ***MOTBCF*** Timer has expired, the critical flow set point determines how long the well will stay open. If the gas flow rate drops below the critical flow set point the ***Critical Flow Bypass*** timer will begin counting down. The control valve will remain open during this time. If the gas flow rate rises above the critical flow set point before the ***Critical Flow Bypass*** timer expires, the timer will reset and the valve will remain open. If the bypass timer expires, the valve will close and the program will go into the ***Time Off*** cycle.

For liquid unloading situations ensure that the Critical Flow Bypass Timer is not set too short to avoid switching to the ***Time Off*** Cycle prematurely.

A fixed value may be entered for the critical flow set point, or the user may enable the critical flow calculation based on Gray's Equation (refer to Appendix F for more information). Ideally the pressure used is from a wellhead-mounted tubing pressure transmitter, although the meter run static pressure may also be used. Values for the water fraction and tubing size must be entered before the calculation is enabled.

- Once setpoints have been entered type a 1 in ***Start/Stop*** on the ***User Display*** screen and click ***Apply***.
- The most recent 10 plunger velocity and arrival time stamp are available on User Display if plunger sensor is installed.
- Changing timer setpoints when the timer is counting will have no effect until the next cycle.
- To force setpoint changes to take effect immediately ***Stop*** and then ***Start*** the mode.
- A critical flow set point change will take effect immediately.

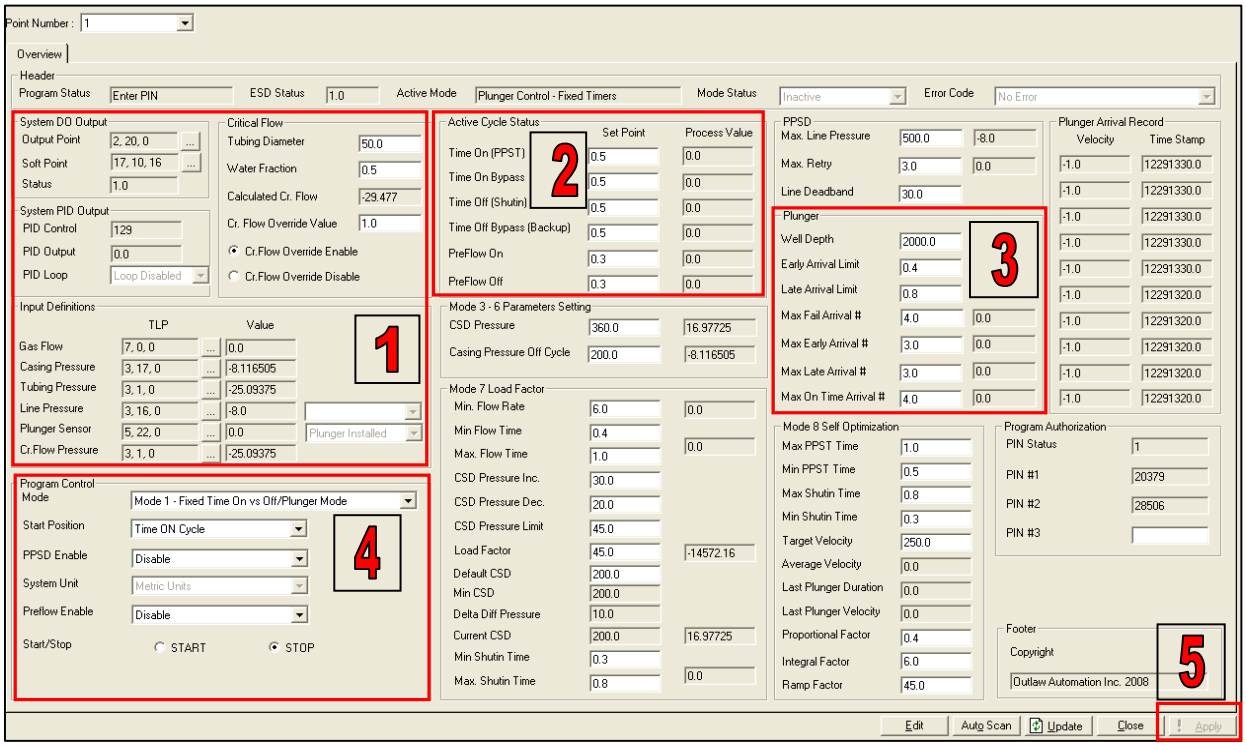

Figure 14 - Mode 2 Configuration

The minimum required configuration on the ***User Display*** screen (following Letter Number on Figure 14):

- STEP 1 – Confirm *all* ***System Input /Output*** Parameters has been probably setup or initialized.
  - If using program internal calculated critical flow, ***SELECT*** "Cr.Flow Override Disabled".
  - If using manual critical flow setpoint, ***SELECT*** "Cr.Flow Override Enabled", also ENTER a Cr.Flow Override Value.
  - Values for the ***Tubing Diameter*** and ***Water Fraction*** must be entered if the Continuous Critical Flow calculation is to be used.
- STEP 2 – Confirm ***Time On***, ***Time On Bypass*** and ***Time Off*** setpoint value has been entered correctly.
- STEP 3 – If plunger sensor is installed, all plunger parameter set points ***MUST*** be initialized or corrected.
- STEP 4 – Confirm program is currently on ***Mode 2***.
- STEP 5 – Select ***START*** and click ***Apply*** button to start optimization program as.

Modes 3 & 4 (Critical Flow vs. Casing / Static Differential Pressure)

Intended Use – Mode 3:
Enhanced On/Off control utilizing well pressure. A Plunger is not required. Use of critical flow allows the on time to vary according to the well's ability to produce gas. Use of casing static delta pressure being less than the set point is included because if a well becomes loaded with liquid when it is flowing, the casing pressure may become considerably greater than the static pressure (DP increases because liquid prevents gas flow up the tubing). If the casing and static pressures are equalized during the shut-in period then this may be considered as a safe condition to resume flow.

Intended Use – Mode 4:
Enhanced On/Off control utilizing well pressure. A plunger is not required. Use of critical flow allows the on time to vary according to the well's ability to produce gas. Use of casing static delta pressure being greater than the set point is included because as a well builds pressure during the shut-in time the casing pressure may become considerably higher than the static pressure. When the well is opened to flow the high casing pressure may aid in lifting liquids and / or the plunger to the surface.

These modes provide automatic On/Off control based on a Critical Flow set point and the Casing Static Delta (CSD) pressure. Both on and off times will vary. Plunger is optional with this mode. The cycle is started in the on or off time according to the Start Position.

For ***Mode 3*** the CSD pressure being less than the entered set point triggers the on cycle.
For ***Mode 4*** the CSD pressure being greater than the entered set point triggers the on cycle.

The Minimum On Time Before Critical Flow Timer (***MOTBCF*** Timer) will begin counting down at the start of the on cycle. The purpose of this timer is to permit flow for a minimum period of time and, if a plunger is installed, to allow enough time for the plunger to arrive. Once the ***MOTBCF*** Timer has expired, the Critical Flow set point determines how long the well will stay open. If the gas flow rate drops below the Critical Flow set point the Critical Flow Bypass timer will begin counting down. The control valve will remain open during this time. If the gas flow rate rises above the critical flow set point during the Critical Flow Bypass Timer the timer will reset and the valve will remain open. If the Critical Flow Bypass Timer expires, the valve will close and the program will go into the ***Time Off*** cycle.

The length of the off cycle is determined by the recovery time of the well. When the ***CSD*** pressure rises above (or drops below) the set point the Time off (**CSD**) Bypass Timer is started. The ***CSD*** pressure must stay above (or below) the entered set point for the duration of the Bypass timer before the valve will open. If the pressure drops below (or rises above) the set point the timer is reset and will start again when the actual pressure variable next rises above (or drops below) the set point.

A fixed value may be entered for the Critical Flow setpoint, or the user may enable the Critical Flow calculation based on the Gray Equation (refer to Appendix F for more information). Ideally the pressure used is from a wellhead-mounted Tubing pressure transmitter, although the meter run static pressure may also be used. Values for the tubing diameter and water fraction must also be entered before the calculation is enabled.

- Once setpoints have been entered type a 1 in ***Start/Stop*** on the ***CONFIG*** screen and click ***Apply***.
- Plunger velocity is available for information. The most recent 10 plunger velocity and arrival time stamp are available on ***User Display*** if plunger sensor is installed.
- Changing timer setpoints when the timer is counting will have no effect until the next cycle.
- Critical Flow and Casing pressure setpoint changes will take effect immediately.

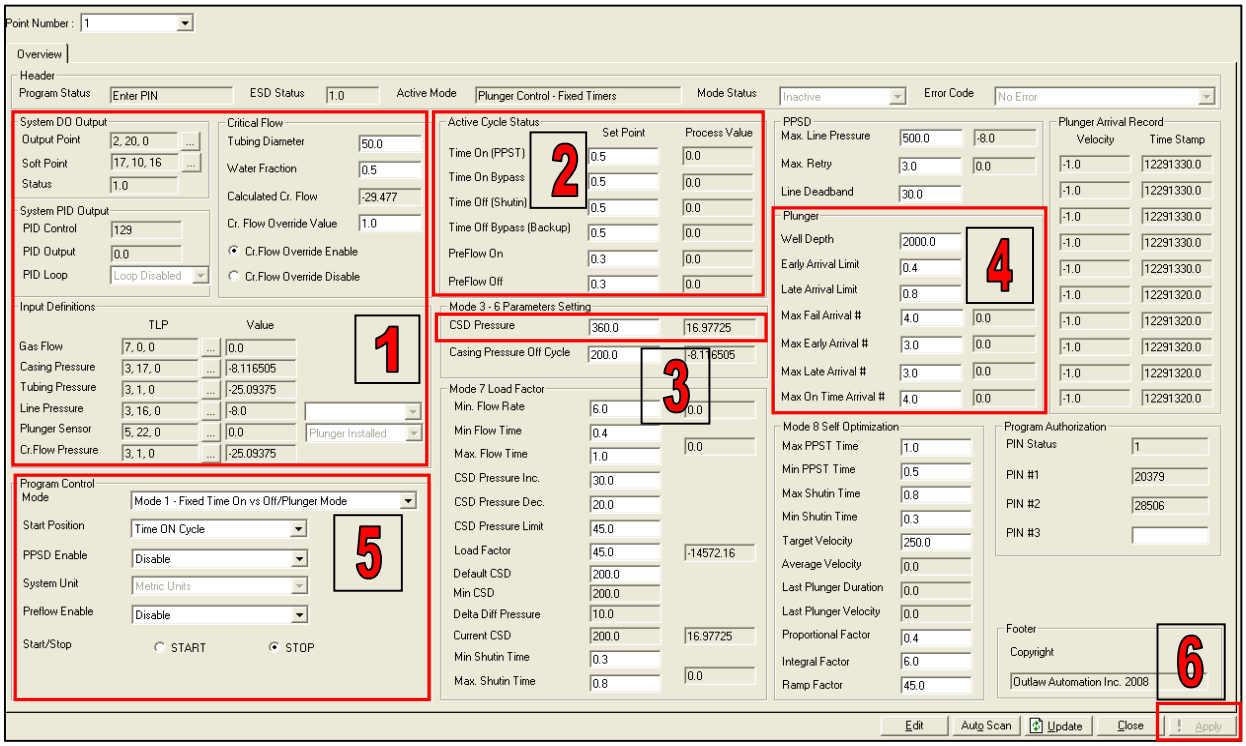

Figure 15 - Mode 3/4 Configuration

The minimum required configuration on the ***User Display*** screen (following Letter Number on Figure 15):

- STEP 1 – Confirm all ***System Input /Output*** Parameters has been probably setup or initialized.
  - If using program internal calculated critical flow, ***SELECT*** "Cr.Flow Override Disabled".
  - If using manual critical flow setpoint, ***SELECT*** "Cr.Flow Override Enabled", also ENTER a Cr.Flow Override Value.
  - Values for the ***Tubing Diameter*** and ***Water Fraction*** must be entered if the Continuous Critical Flow calculation is to be used.
- STEP 2 – Confirm ***Time On*** and ***Time Off*** setpoint value has been entered correctly.
- STEP 3 – Enter ***CSD Pressure SP*** value.
- STEP 4 – If plunger sensor is installed, all plunger parameter set points ***MUST*** be initialized or corrected.
- STEP 5 – Confirm program is currently on ***Mode 3 or Mode 4***.
- STEP 6 – Select ***START*** and click ***Apply*** button to start optimization program.

Mode 5 (Casing Static Differential Pressure vs. Time Off)

Intended Use:
Enhanced On / Off control utilizing Casing pressure. A Plunger is not required. Use of CSD allows the on time to vary according to the well's ability to produce gas while monitoring for liquid loading. As a well becomes loaded with liquid when it is flowing, the Casing pressure may become considerably greater than the Static pressure (CSD increases because liquid prevents gas flow up the tubing).

This mode provides automatic On/Off control based on the casing static delta pressure set point and a fixed off time. Plunger is optional with this mode. The amount of time that the valve will be open will vary depending on the characteristics of the well. The cycle is started in the on or off time according to the Start Position.

The Minimum On Time Before Casing Static Delta Pressure Timer (***MOTBCSD*** Timer) will begin counting down at the start of the on cycle. The purpose of this timer is to permit flow for a minimum period of time and, if a plunger is installed, to allow enough time for the plunger to arrive. Once the ***MOTBCSD*** timer has expired, the ***CSD*** Set Point determines how long the well will stay open. While the ***CSD*** Pressure remains below the set point the valve will remain open. When ***CSD*** Pressure rises above the set point the Casing Static Delta Pressure Bypass Timer (***CSDB*** Timer) will begin counting down. The control valve will remain open during this time. If the pressure drops below the set point during the ***CSDB*** Timer, the timer will reset and the valve will remain open. If the ***CSDB*** Timer expires, the valve will close and go into the time off phase. Once the Off Timer has counted down the valve will open.

- Once setpoints have been entered type a 1 in ***Start/Stop*** on the ***CONFIG*** screen and click ***Apply***.
- Plunger velocity is available for information. The most recent 10 plunger velocity and arrival time stamp are available on User Display if plunger sensor is installed.
- Changing the Off timer setpoint when the timer is counting will have no effect until the next cycle.
- To force setpoint changes to take effect immediately ***Stop*** and then ***Start*** the mode.

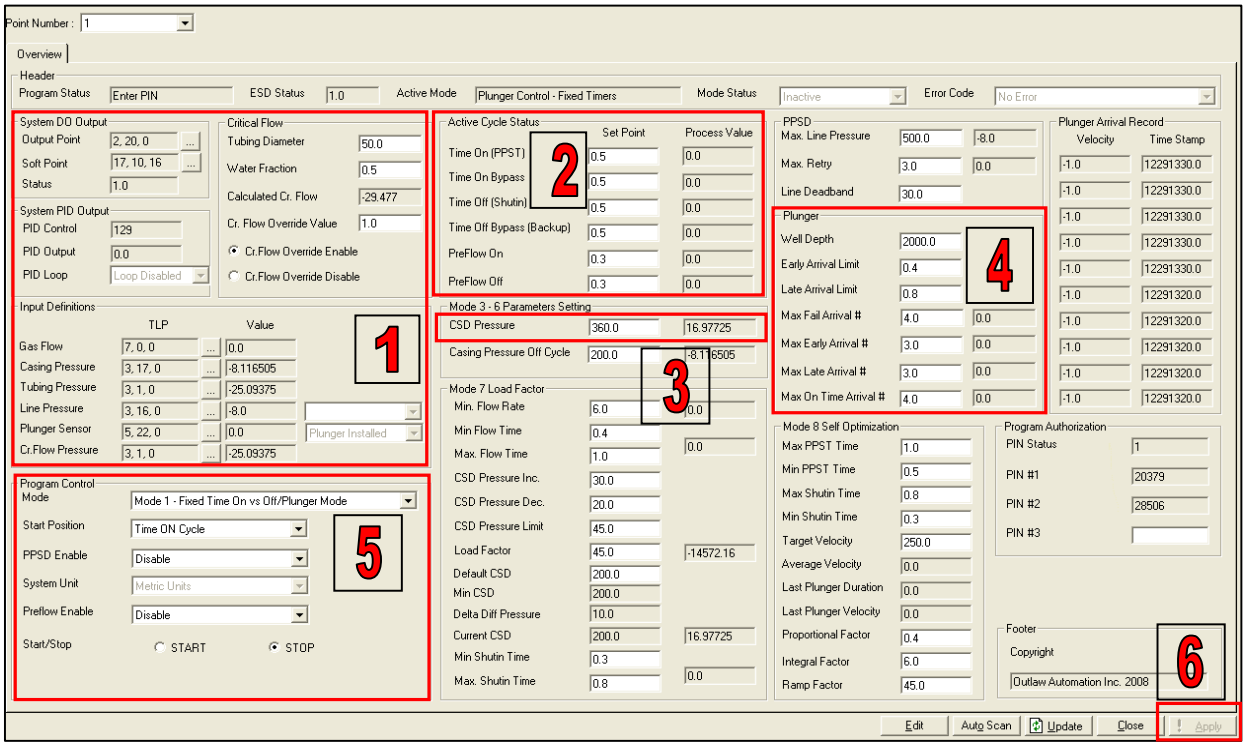

Figure 16 - Mode 5 Configuration

The minimum required configuration on the ***User Display*** screen (following Letter Number on Figure 16):

- STEP 1 – Confirm all ***System Input /Output*** Parameters has been probably setup or initialized.
- STEP 2 – Confirm ***Time On, Time On Bypass*** and ***Time Off*** setpoint value has been entered correctly.
- STEP 3 – Enter ***CSD Pressure SP*** value.
- STEP 4 – If plunger sensor is installed, all plunger parameter set points ***MUST*** be initialized or corrected.
- STEP 5 – Confirm program is currently on ***Mode 5***.
- STEP 6 – Select ***START*** and click ***Apply*** button to start optimization program.

Mode 6 (Critical Flow vs. Casing Pressure)

Intended Use:

Enhanced On / Off control utilizing well pressure. A Plunger is not required. Use of Casing pressure allows the off time to vary according to the well's ability to build pressure.

This mode consists of automatic On/Off control based on a critical flow set point and a casing pressure value. Both on and off times will vary. Plunger is optional with this mode. The cycle is started in the on or off time according to the Start Position.

The Minimum On Time Before Critical Flow Timer (***MOTBCF*** Timer) will begin counting down at the start of the on cycle. The purpose of this timer is to permit flow for a minimum period of time and, if a plunger is installed, to allow enough time for the plunger to arrive. Once the ***MOTBCF*** Timer has expired, the critical flow set point determines how long the well will stay open. If the gas flow rate drops below the critical flow set point the ***Critical Flow Bypass*** Timer will begin counting down. The control valve will remain open during this time. If the gas flow rate falls below the Critical Flow set point during the ***Critical Flow Bypass*** Timer will reset and the valve will remain open. If the bypass timer expires, the valve will close and the program will go into the ***Time Off*** cycle.

The length of the off cycle is determined by the recovery time of the well – the pressure value will have dropped while the well was flowing and will increase over time when the well is shut in. The actual pressure is compared against an entered set point. When the actual pressure rises above the set point a bypass timer is started. The pressure must stay above the entered set point for the duration of the bypass timer before the valve will open. If the pressure drops below the set point the timer is reset and will start again when the actual pressure next rises above the set point.

A fixed value may be entered for the critical flow set point, or the user may enable the critical flow calculation based on the Gray Equation, refer to Appendix F – Continuous Critical Flow Calculation (Gray Equation)for more information. Ideally the pressure used is from a wellhead-mounted tubing pressure transmitter, although the meter run static pressure may also be used. Values for the tubing diameter and water fraction must also be entered before the calculation is enabled.

- Once setpoints have been entered type a 1 in ***Start/Stop*** on the **CONFIG** screen and click ***Apply***.
- Plunger velocity is available for information. The most recent 10 plunger velocity and arrival time stamp are available on User Display if plunger sensor is installed.
- Critical Flow and pressure setpoint changes will take effect immediately.
- A Bypass Timer setpoint change will take effect on the next cycle.

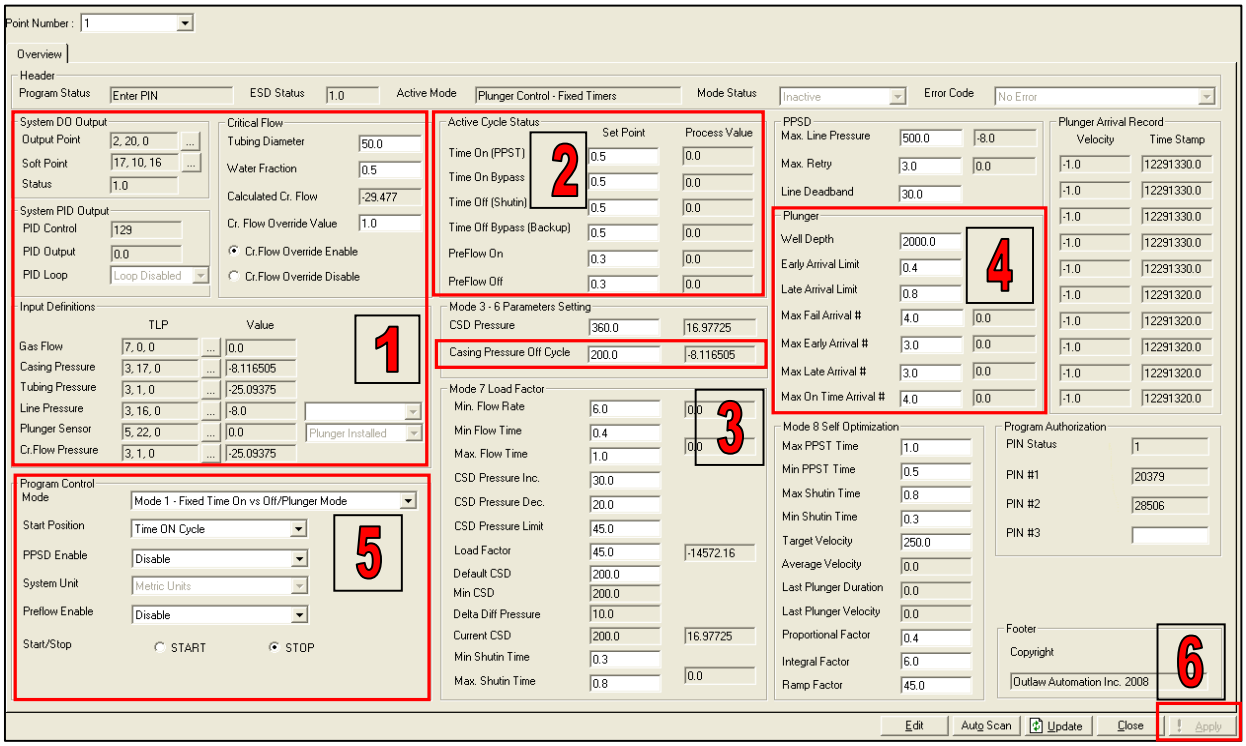

Figure 17 - Mode 6 Configuration

The minimum required configuration on the ***User Display*** screen (following Letter Number on Figure 17):

- STEP 1 – Confirm all ***System Input /Output*** Parameters has been probably setup or initialized.
  - If using program internal calculated critical flow, ***SELECT*** "Cr.Flow Override Disabled".
  - If using manual critical flow setpoint, ***SELECT*** "Cr.Flow Override Enabled", also ENTER a Cr.Flow Override Value.
  - Values for the ***Tubing Diameter*** and ***Water Fraction*** must be entered if the Continuous Critical Flow calculation is to be used.
- STEP 2 – Confirm ***Time On, Time On Bypass*** and ***Time Off*** setpoint value has been entered correctly.
- STEP 3 – Enter ***Casing Pressure SP*** value.
- STEP 4 – If plunger sensor is installed, all plunger parameter set points ***MUST*** be initialized or corrected.
- STEP 5 – Confirm program is currently on ***Mode 6***.
- STEP 6 – Select ***START*** and click ***Apply*** button to start optimization program.

Mode 7 (Critical Flow vs. Load Factor < Set Point)

Intended Use:
Enhanced On/Off control utilizing a calculated load factor value. A plunger is not required. Use of load factor allows the off time to vary according to the well's ability to build pressure.

This mode consists of automatic On /Off control based on a critical flow set point and a calculated load factor value (refer to Appendix H for more information). Both on and off times will vary. Plunger is optional with this mode. The cycle is started in the on or off time according to the Start Position.

The Minimum On Time before Critical Flow Timer (***MOTBCF*** Timer) will begin counting down at the start of the on cycle. The purpose of this timer is to permit flow for a minimum period of time and, if a plunger is installed, to allow enough time for the plunger to arrive. Once the ***MOTBCF*** Timer has expired, the Critical Flow set point determines how long the well will stay open. If the gas flow rate drops below the Critical Flow set point the ***Critical Flow Bypass*** timer will begin counting down. The control valve will remain open during this time. If the gas flow rate rises above the Critical Flow set point during the ***Critical Flow Bypass*** Timer will reset and the valve will remain open. If the bypass timer expires, the valve will close and the program will go into the ***Time Off*** cycle.

The length of the off cycle is determined by the recovery time of the well – the calculated load factor value will have increased while the well was flowing and will decrease over time when the well is shut in. The calculated load factor value is compared against an entered set point. When the calculated load factor value falls below the set point a bypass timer is started. The pressure must stay below the entered set point for the duration of the bypass timer before the valve will open. If the load factor value rises above the set point the timer is reset and will start again when the load factor value falls below the set point.

A fixed value may be entered for the Critical Flow set point, or the user may enable the Critical Flow calculation based on the Gray Equation (refer to Appendix F for more information). Ideally the pressure used is from a wellhead-mounted Tubing pressure transmitter, although the meter run static pressure may also be used. Values for the tubing diameter and water fraction must also be entered before the calculation is enabled.

- Once setpoints have been entered type a 1 in ***Start/Stop*** on the ***CONFIG*** screen and click ***Apply***.
- Plunger velocity is available for information. The most recent 10 plunger velocity and arrival time stamp are available on ***User Display*** if plunger sensor is installed.
- Critical Flow and pressure setpoint changes will take effect immediately.
- Changing the set point for the active timer will have no effect until the next cycle.

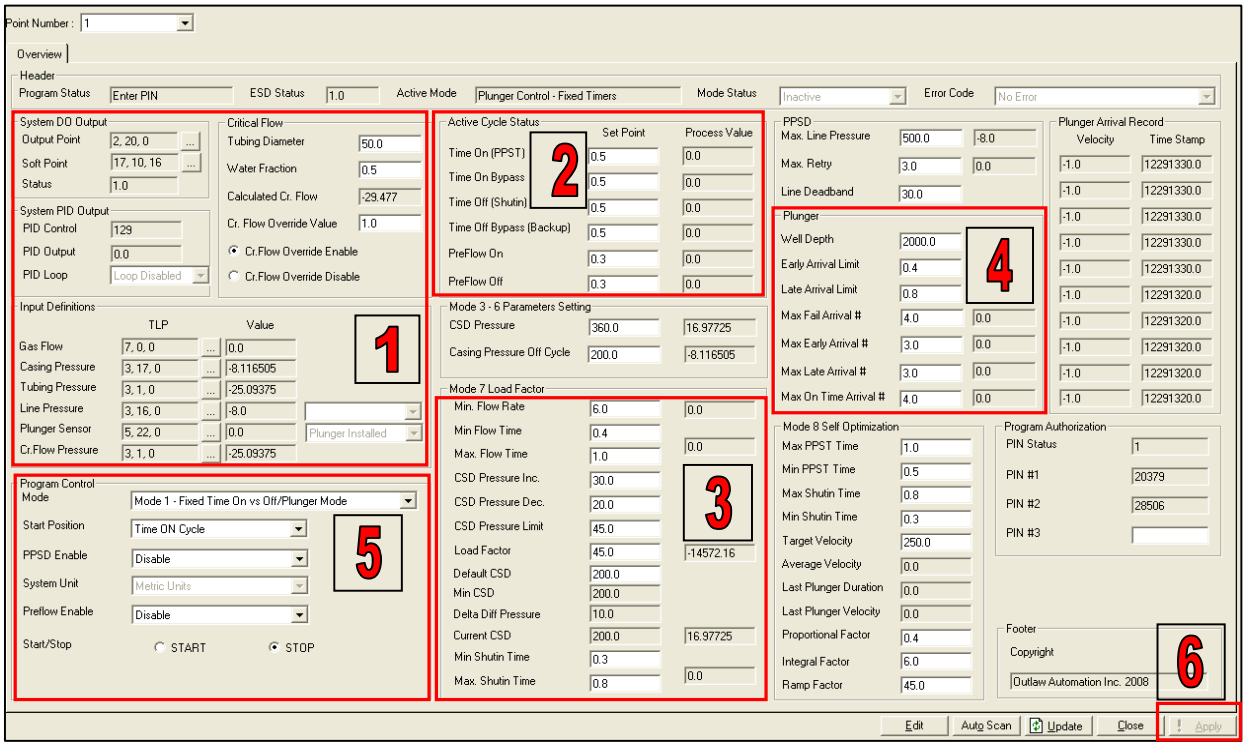

Figure 18 - Mode 7 Configuration

The minimum required configuration on the **User Display** screen (following Letter Number on Figure 18):

- STEP 1 – Confirm all ***System Input /Output*** Parameters has been probably setup or initialized.
  - If using program internal calculated critical flow, ***SELECT*** "Cr.Flow Override Disabled".
  - If using manual critical flow setpoint, ***SELECT*** "Cr.Flow Override Enabled", also ENTER a Cr.Flow Override Value.
  - Values for the ***Tubing Diameter*** and ***Water Fraction*** must be entered if the Continuous Critical Flow calculation is to be used.
- STEP 2 – Confirm ***Time On (PPST), Time On Bypass*** and ***Time Off (Shut in)*** setpoint value has been entered correctly.
- STEP 3 – All parameters in ***Mode 7*** **MUST** be properly initialized.
- STEP 4 – If plunger sensor is installed, all plunger parameter set points ***MUST*** be initialized or corrected.
- STEP 5 – Confirm program is currently on ***Mode 7***.
- STEP 6 – Select ***START*** and click ***Apply*** button to start optimization program.

Mode 8 (Self Optimization)

Intended Use:

Enhanced On / Off control with the requirement that a plunger and plunger arrival sensor have been installed. Timer setpoints will be automatically adjusted in order that the plunger arrival velocity matches the calculated average for the previous arrivals.

This mode uses four different timers to cycle the well on and off based on the plungers arrival or failure to arrive. A set of correction factors is used to adjust the Post Plunger Sales Time (PPST) and Time Off Timer values so that the plunger arrival velocity approaches an entered target value. Process variables and associated set points are not used. The cycle is started in the on or off time according to the Start Position.

Once set points have been entered set the Program On/Off Command to 1.
Changing the set point for the active timer will have no effect until the next cycle.
To force set point changes to take effect immediately stop and then restart the mode.

The four different timers used to cycle the well on and off are:

Plunger Bypass Timer is the initial flow time during which the plunger is expected to arrive. Plunger status is monitored; if it arrives during the count of this timer the arrival time and velocity are noted and the timer stops without timing down completely.

Post Plunger Sales Timer (PPST) is the amount of time the well will remain open after the plunger arrival is detected. This portion of the cycle will only execute if the plunger arrival is detected during the Plunger Bypass Timer.

Time Off Timer is the amount of time for the well is shut in to build pressure. This timer is followed by the Plunger Bypass Timer.

Back Up Timer is activated when the plunger fails to arrive or the late arrival count exceeds or is equal to the late arrival set point. This timer is followed by the Plunger Bypass Timer.

Mode 8 - Self Optimization Supplementary Information

Target Velocity is the desired plunger arrival velocity that uses either metric or imperial units determined by the RTU configuration. Target Velocity and Well Depth must be positive numbers. A suggested range for plunger arrival velocity is 182 to 275 meters/minute (600 to 900 feet/minute).

A set of plunger arrival set points is available to fine control the sequence of the On/Off Cycles.

If Maximum Early Plunger Arrivals Preset is zero, the fast plunger protection functionality ius disabled. Otherwise, if the plunger early arrival counter exceeds its set point, the program stops and sets up fast plunger arrival flag for operators intervention.

If Maximum Late Plunger Arrivals Preset is zero, the plunger late arrival count does not affect the On/Off cycle. Otherwise, if the plunger late arrival counter exceeds its set point, the Back Up Off Cycle starts in place of the Time Off Cycle. This gives the well more time to build up the pressure and let the plunger fully drop to the bottom.

If Maximum Failed Plunger Arrivals Preset is zero, the plunger failed arrival counter does not affect the On/Off cycle. Otherwise, if the plunger late arrival counter exceeds its set point, the Back Up Off cycle starts in place of the Time Off Cycle. This gives the well more time to build up the pressure and let the plunger fully drop to the bottom.

The Early Plunger Arrivals Time Preset and Late Plunger Arrivals Time Preset determine the limits for a 'good' plunger arrival time. Both values must be less than the Plunger Bypass Timer set point and the Early Plunger Arrivals Time Preset must be less than the Late Plunger Arrivals Time Preset.

The Maximum PPST Timer Preset and Minimum PPST Timer Preset determine the adjustment range that program calculates for the PPST value.

The Minimum Shut-in Time Preset is initialized at 45 minutes if a value of zero is entered. This value should be adjusted as required to allow sufficient time for the plunger to fall back to the bottom of the well bore given a typical fall rate of 45 meters/minute. Calculate the time required by dividing the depth of the well by 45 meters/minute.

Correction Factors:

Average velocity is calculated from the three most recent valid timestamps for plunger arrival. The program will use the entered values to modify ΔT which can be expressed as:

$$\Delta T = C_p \times \Delta V + \int \Delta V C_i dt$$

Where: ΔV= Average velocity – Target velocity.

C_p and C_i represent the constants of the proportional and integral parts of the equation respectively. These values are input by the operator and are labeled as PPST Correction Factor Cp and PPST Correction Factor Ci in the Modbus mapping.

A third Correction Factor features a ramp setting labeled as PPST Correction Factor Ramp Rate Coefficient which will limit maximum changes in ΔT every cycle.

For an illustration of how this equation functions see Figure 19 - Mode 8 Correction Factor Logic

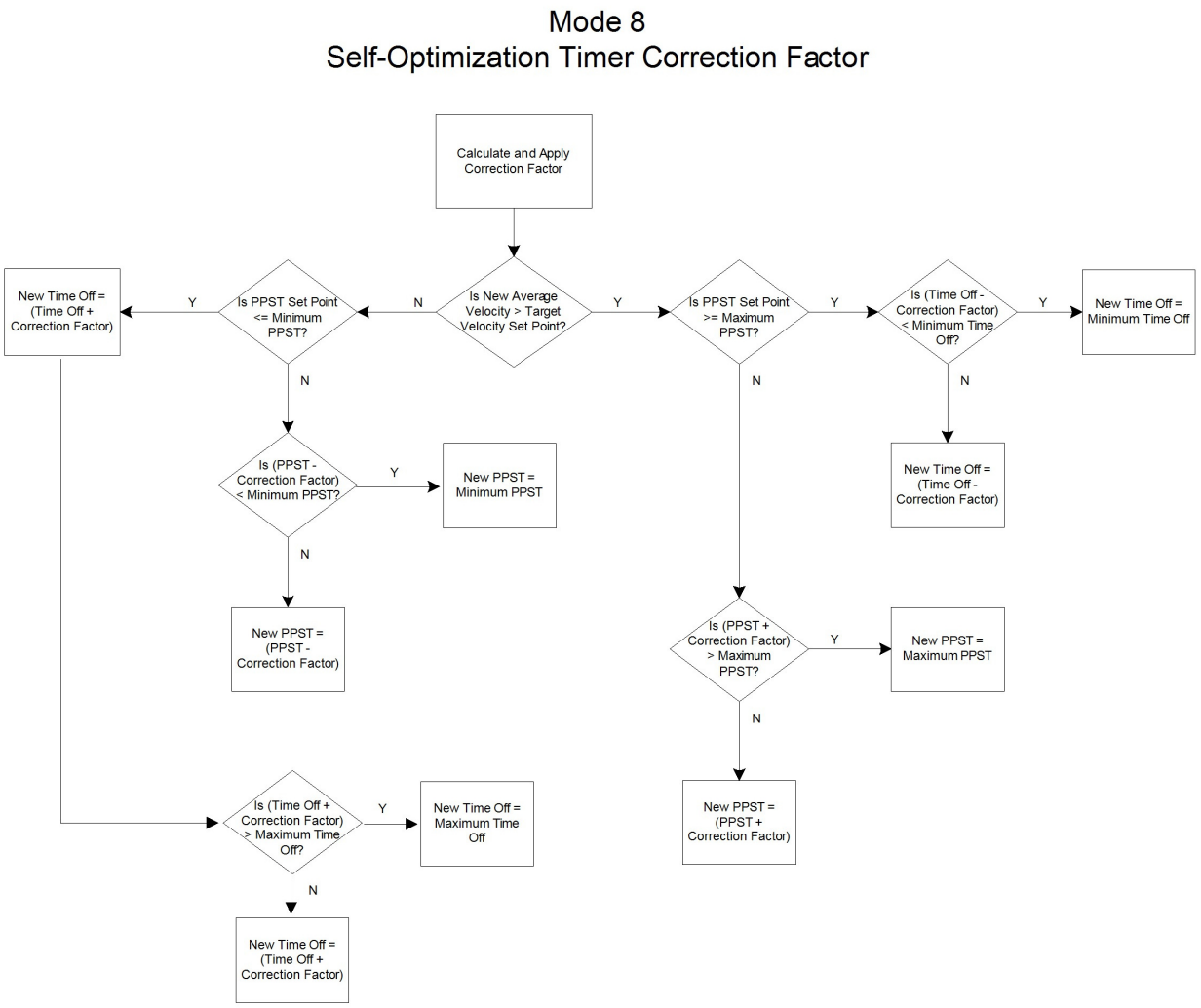

Figure 19 - Mode 8 Correction Factor Logic

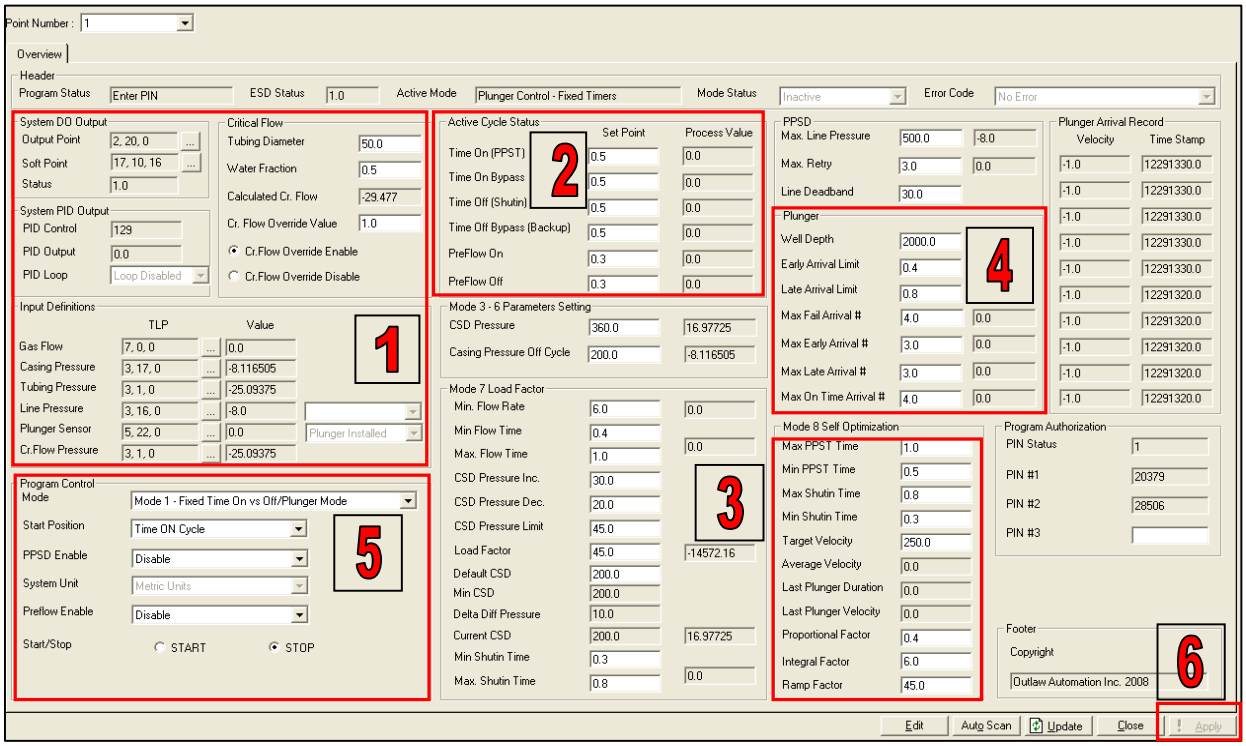

Figure 20 - Mode 8 Configuration

The minimum required configuration on the **User Display** screen (following Letter Number on Figure 20):

- STEP 1 – Confirm all ***System Input /Output*** Parameters has been probably setup or initialized.
- STEP 2 – Confirm ***Time On (PPST), Time On Bypass*** and ***Time Off (Shut in)*** setpoint value has been entered correctly.
- STEP 3 – All parameters in ***Mode 8*** **MUST** be properly initialized.
- STEP 4 – Plunger sensor installation is Mandatory in ***Mode 8***. All plunger parameter set points ***MUST*** be initialized or corrected.
- STEP 5 – Confirm program is currently on ***Mode 8***.
- STEP 6 – Select ***START*** and click ***Apply*** button to start optimization program.

Appendix A – Available Control Modes

Table 2 - PID and AGA Controls

RTU Type	Max Number of PID	Max Number of AGA
ROC 306	6	3
ROC 312	6	3
ROC 364	16	5
ROC 407	4	4
ROC 103	1	1
ROC 107	8	4

Table 3 - Control Modes Summary

Mode	Time On Cycle	Time Off Cycle
1 – Time On vs. Time Off	Time On	Time Off
2 – Critical Flow vs. Time Off	Critical Flow	Time Off
3 – Critical Flow vs. Diff. Pressure	Critical Flow	DP < SP
4 – Critical Flow vs. Diff. Pressure	Critical Flow	DP > SP
5 – Diff. Pressure vs. Time Off	DP > SP	Time Off
6 – Critical Flow vs. Casing Pressure	Critical Flow	Casing Pressure > SP
7 – Load Factor	Critical Flow and CSD pressure	Load Factor
8 – Self Optimization	Self Optimization	

Table 4 - Control Modes - Hardware Requirements

Mode	Control Valve	Auxiliary Analog Input (Pressure Transmitter)	Plunger Arrival Sensor
1	Yes	No	Optional
2	Yes	No	Optional
3	Yes	Yes	Optional
4	Yes	Yes	Optional
5	Yes	Yes	Optional
6	Yes	Yes	Optional
7	Yes	Yes	Optional
8	Yes	No	Yes

There are some optional features common to all control modes.

1. **PPSD – Pipeline Pressure Shut Down**
   The purpose of PPSD control is to prevent sudden line pressure increase due to compressor malfunction. The program will shut down the control valve if line pressure exceeds a preset point.

   - Line Pressure Transmitter Installed
     Line Pressure >= PPSD SP – Deadband — Stay in **Time Off** cycle
     Line Pressure < PPSD SP – Deadband — Back to Normal Operation
   - Line Pressure Transmitter Not Installed
     Line Pressure >= PPSD SP – Deadband — Normal Operation, max_retry_on_low_flow counter + 1
     max_retry_on_low_flow >= Max. Retry SP — Shut Down Valve, Terminate Program

     Due to the fact that no line pressure transmitter is installed, the program is not able to detect line pressure when control valve is closed. Therefore the program can **ONLY** be turned back **ON** manually by operator after inspection.

2. **Pre-Flow Cycle**
   The premise behind this option is to allow a short flow time to let liquid into the tubing from the bottom of the well bore, followed by a short off time to allow the plunger to fall back. The main On/Off cycle is then started. Set the Pre-Flow Enable to 1 to enable this option. The on time is set at 40 seconds and the off time is set at three minutes.

3. **Plunger Control**

   a. **Early Plunger Arrival (Fast Plunger)**
      If the number of consecutive plunger early arrival exceeds the ***Max. Early Arrival*** limit, the program will shut down well control value and terminate program immediately.

   b. **Late Plunger Arrival**
      When the number of consecutive plunger late arrival exceeds the ***Max. Late Arrival*** limit, the program will activate ***Backup*** cycle instead of normal ***Time Off*** cycle after ***PPST*** cycle.

   c. **Failure Arrival**
      If program is not able to receive a plunger arrival signal before the **Time On Bypass** counter expires, the program will activate **Backup** cycle, which gives well extra time off to build gas pressure and reset the plunger to the bottom of the well.

      In ***Mode 1-7***:
      Fail Arrival < Max. Fail Arrival — Go to **Backup** cycle
      Fail Arrival >= Max. Fail Arrival — Go to **Backup** cycle
      In ***Mode 8 Self Optimization***:
      Fail Arrival < Max. Fail Arrival — Go to **Time Off** cycle
      Fail Arrival >= Max. Fail Arrival — Go to **Backup** cycle

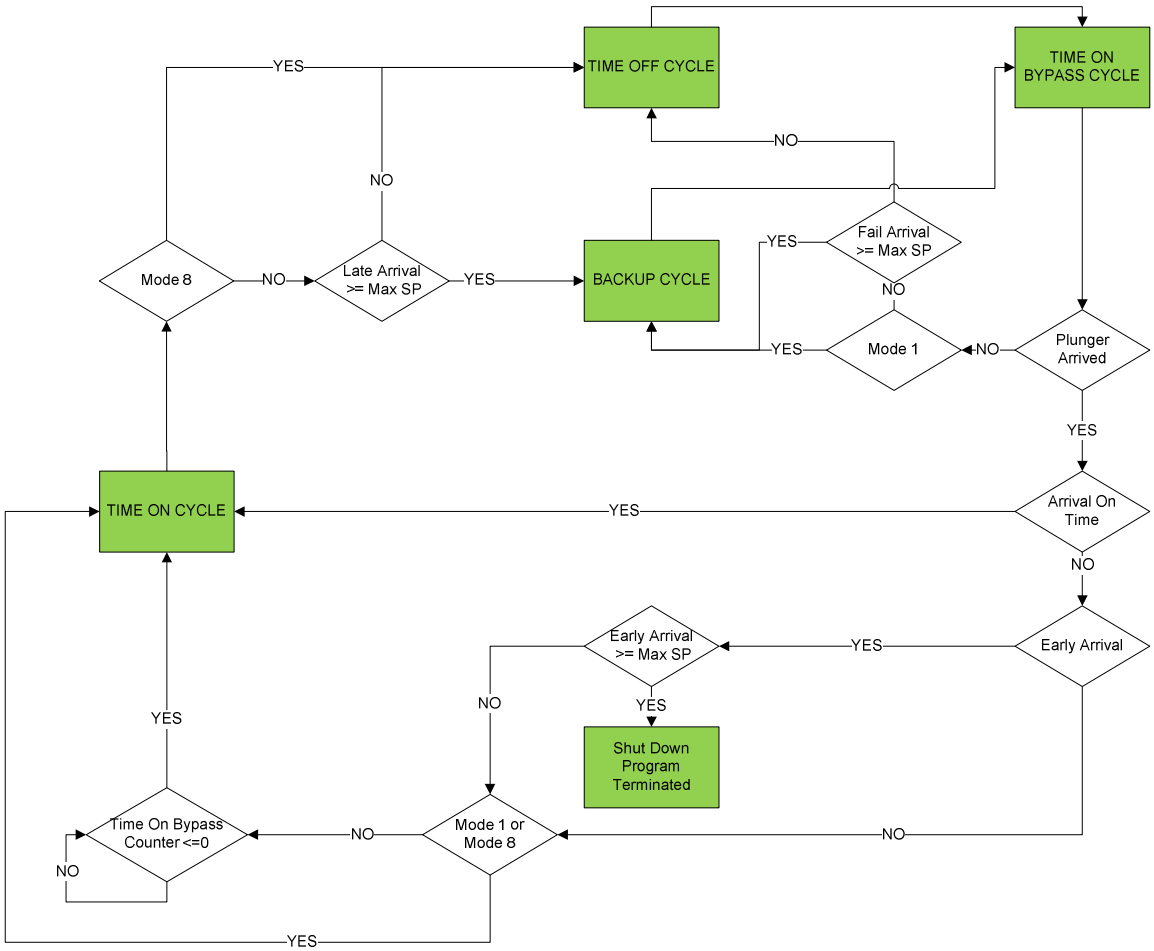

Figure 21 - Plunger State Diagram

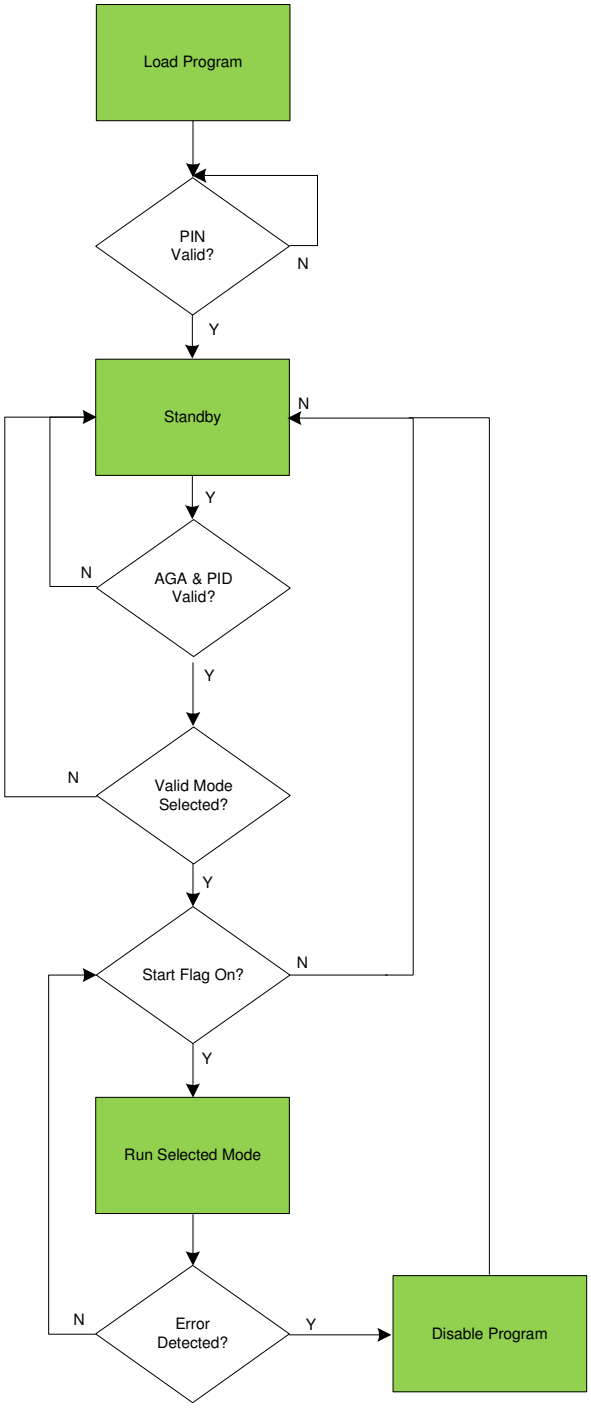

Figure 22 - Program Operation

Appendix B – Glossary

The following describes terms and abbreviations used in this manual.

AGA: American Gas Association flow calculation method.

CSD: Casing / Static Differential pressure.

DP: Differential pressure, the difference between two well pressures such as Casing and Tubing. Not to be confused with the meter run (orifice) differential pressure used in the gas flow calculation.

Gray's Equation: A method to determine the critical velocity required to maintain liquid droplets in the gas stream.

Loading: The tendency for liquids to accumulate and prevent gas flow.

LOI: Local operator interface communications connection.

PID: Proportional, Integral and Derivative control algorithm.

PPST: Post Plunger Sales Time. The length of time gas flow is maintained after the plunger arrives.

SP: Setpoint

TLP: ROC Point Type, Logical Index, Parameter Number definition.

Appendix C – Parameter Definition and Initialization

Table 5 - Parameter Definition and Initialization

Parameter Name	Definition	Initial Value
	Header	
Program Status	Current program running status	"Enter PIN"
ESD Status	Current ESD status: 1 – No ESD, 0 – ESD	1
Active Mode	Current Optimization Control Mode	"Time On vs. Time Off"
Mode Status	Current program cycle status (see *Appendix D*)	Inactive
Error Code	Current Error Status (see *Appendix D*)	No Error
	System DO Output	
Output Point	Valve Control DO TLP	2, 20, 0
Soft Point	Valve Control Output in Soft Point TLP	17, 10, 16
Status	Valve Control DO Status: 1 – Enabled, 0 – Disabled	1
	System PID Output	
PID Control	Debug used TLP, see *ROC Protocol User Manual*	48, 0, 1
PID Output	Valve Control PID Output TLP	48, 0, 25
PID Loop	0 – Loop Disabled, 1 – Primary Loop, 2 – Override Loop	"Loop Disabled" (48, 0, 2)
	Critical Flow	
Tubing Diameter	The diameter of the tubing string, used when critical flow calculation is activated.	50
Water Fraction	The fraction of water in the produced liquids, used when critical flow calculation is activated.	0.0
Calculated Cr. Flow	Critical Flow Setpoint calculated by program	READ ONLY
Cr. Flow Override Valve	Critical Flow Manual Setpoint	1.0
Cr. Flow Override Enable	Enable Critical Flow Manual Control	Selected
Cr. Flow Override Disable	Disable Critical Flow Manual Control	Not Selected
	Input Definition	
Gas Flow	Instant Flow Rate TLP	7, 0, 0
Casing Pressure	Instant Casing Pressure TLP	3, 17, 0
Tubing Pressure	Instant Tubing Pressure TLP	3, 1, 0
Line Pressure	Instant Line Pressure TLP	3, 16, 0
Plunger Sensor	Plunger Sensor DI or PI TLP	5, 22, 0 (PI)
Cr. Flow Pressure	Critical Flow Pressure TLP	3, 1, 0
	Program Control	
Mode	Select from 8 Optimization Modes	Mode 1
Start Position	0 – Flow Control, 1 – Time On, 2 – Time Off, 3 – Error	Flow Control
PPSD Enable	Pipeline Pressure Shut Down Function Switch	Disabled
System Unit	0 – Imperial Unit, 1 – Metric Unit	Metric Unit
Preflow Enable	Preflow Function Switch	Disabled
Start/Stop	Program START/STOP Switch	STOP
	Active Cycle Status	
Time On (PPST)	Time On or PPST Cycle Set Point	1.0
Time On Bypass	Time On Bypass (Mode 1, 5, 8) Critical Bypass (Mode2, 3, 4, 6) Load Factor Bypass (Mode 7) Set Point	1.0
Time Off (Shut In)	Time Off or Shut In Cycle Set Point	1.0
Time Off Bypass (Backup)	Time Off Bypass or Backup Cycle Set Point	1.0
Preflow On	Preflow On Cycle Set Point	0.3
Preflow Off	Preflow Off Cycle Set Point	0.5

Mode 3 – 6 Parameter Setting		
CSD Pressure	Casing Static Diff Pressure Set Point(Mode 3, 4, 5)	500 kPa
Casing Pressure Off Cycle	Casing Pressure Set Point for Mode 6 Off Cycle	2000 kPa
Mode 7 Load Factor		
Min. Flow Rate	Minimum Flow Rate Set Point	4 E3M3/Day
Min. Flow Time	Minimum Flow Time Set Point	45 min
Max. Flow Time	Maximum Flow Time Set Point	180 min
CSD Pressure Inc.	Casing Static Diff Pressure Increment Set Point	20 kPa
CSD Pressure Dec.	Casing Static Diff Pressure Decrement Set Point	20 kPa
CSD Pressure Limit	Casing Static Diff Pressure Change Limit	100 kPa
Load Factor	(Casing – Static)/(Casing – Line)	45%
Default CSD	Current CSD = Min. CSD + Default CSD + Delta Diff Pressure	150 kPa
Min. CSD		READ ONLY
Delta Diff Pressure		READ ONLY
Current CSD		READ ONLY
Min. Shutin Time	Minimum Shut In Time Set Point	60 min
Max. Shutin Time	Maximum Shut In Time Set Point	120 min
PPSD		
Max. Line Pressure	Maximum Line Pressure Set Point	1000 kPa
Max. Retry	Maximum Number of Retry when line pressure > Max. line pressure and line pressure transmitter is not installed	2
Line Deadband	Program will only recognize line pressure back to normal when line pressure <= Max. line pressure – Line deadband	300 kPa
Plunger		
Well Depth	The Depth of Well, Only used with Plunger Sensor.	2000 m
Early Arrival Limit	The maximum value of early arrival	15 min
Late Arrival Limit	The minimum value of late arrival	30 min
Max. Fail Arrival #	Maximum number of consecutive fail arrival set point	5
Max. Early Arrival #	Maximum number of consecutive early arrival set point	2
Max. Late Arrival #	Maximum number of consecutive late arrival set point	5
Mode 8 Self Optimization		
Max. PPST Time	Maximum PPST counter set point	2880 min
Min. PPST Time	Minimum PPST counter set point	2 min
Min. Shutin Time	Minimum Shut In time set point	45 min
Max. Shutin Time	Maximum Shut In time set point	180 min
Target Velocity	Target plunger arrival velocity	225 m/min
Average Velocity	Average plunger arrival velocity	READ ONLY
Last Plunger Duration	The latest plunger arrival duration	READ ONLY
Last Plunger Velocity	The latest plunger arrival velocity	READ ONLY
Proportional Factor	P factor in PI control	0.01
Integral Factor	I factor in PI control	0.01
Ramp Factor	Ramp Factor in PI control	1 min

Appendix D – Troubleshooting

Table 6 - Troubleshooting List

Symptom	Cause	Solution
Program status message displays 'Enter PIN'	Installed program has not been authorized	Enter authorization code
Program status message displays 'Manual', Optimization Program will not run	PID scanning is not enabled	Set Optimization Program Start/ Stop flag to 0; enable PID scanning on PID configuration screen. Set Start/Stop flag to 1.
Cannot define valve PID	PID is not enabled	Set PID to active in ROC Information settings
Cannot define Gas Flow	AGA is not enabled	Set AGA calculation to Active in ROC Information settings
Timers start in off cycle when on cycle is desired	Start control is not set	Set Start Control to 1 on Engine screen
Values entered for setpoints on user program configuration screens have no effect and are overwritten with different values	SPT Input and/or Output values are non-zero	Clear entries for control points (enter 0 or set as Undefined)
Values entered for setpoints from SCADA host have no effect	SPT Input and/or Output values have not been assigned; SCADA host configuration errors	Define Start/Stop, Mode, SPT Input and SPT Output points; Check SCADA host configuration
Plunger Duration is non-zero but Plunger velocity is zero	Well Depth is zero	Define Well Depth
Average velocity does not equal target velocity	Correction Factor #1 is too large	Enter a smaller value for Correction Factor #1

Table 7 - Error Code List

code	message	solution
0	no error	
101	program execution error	Problem with RTU, contact Outlaw Automation
102	meter run not configured	N/A in RTU
103	AGA calculation stopped	N/A in RTU
104	program authorization PIN invalid	Acquire the Authorization Code from Outlaw
105	too many configured meter runs	Contact Outlaw Automation for details
106	too many total meter runs	Contact Outlaw Automation for details
107	invalid mode	Selection must be between 1 and 8
108	plunger arrival sensor address invalid	Valid address is between 0 and 4096
109	casing PT address invalid	Valid address is between 40001 and 49999, or 0
110	tubing PT address invalid	Valid address is between 40001 and 49999, or 0
111	line PT address invalid	Valid address is between 40001 and 49999, or 0
112	line pressure hi shut-in	Restart the program once line pressure is normal
113	line pressure lo shut-in	Restart the program once line pressure is normal
114	fast plunger shut-in	Restart the program once fast plunger is addressed
115	program stopped by operator	Restart the program at operators discretion
116	ESD status address invalid	Valid address is between 0 and 4096
117	well ESD shut-in	Program is still running, but holds on ESD conditions
118	start Position invalid	Valid value is 0 , 1 and 2.
119	plunger not installed for self optimization mode	Installed plunger before select Mode 8
120	Gas Flow Sensor Address Invalid	

Table 8 - Mode Status Code List

Mode Status Code	Description
0	Inactive
2001	Time On
2002	Time On Bypass
2003	Time Off
2004	Time Off Bypass
2005	Preflow On
2006	Preflow Off
2007	Critical Bypass (Mode 2, 3, 4 and 6)
2008	CSD Bypass (Mode 5)
2009	Stable Flow
2010	Line Pressure High Shut In
2011	Plunger Rising
2012	PPST
2013	Casing Bypass (Mode 6 Off Cycle)
2014	Backup Cycle
2015	Load Factor Bypass

Appendix E – Plunger Sensor Wiring & Velocity Calculations

Sensor Wiring:

Using a plunger sensor wired directly to a Discrete Input point on a RTU may result in the plunger arrival signal being 'missed' during the RTU's I/O scan. This occurs because of the short duration of the signal from the plunger sensor. Some plunger sensors produce an output signal with a 1 second duration. This may be too short.

If the plunger sensor does not allow for the user to modify the output signal, the signal may be manipulated with readily available manufactured electronic devices so that the signal is on for a longer period of time. This has been tested successfully at the time of writing this manual.

Using a plunger sensor wired directly to a Pulse Input point on a RTU will result in the RTU detecting the plunger arrival signal. This has been tested successfully at the time of writing this manual. A parameter that may need to be adjusted for a particular sensor is the ***Filter Time*** on the Advanced Tab of the PI configuration window. A value of 0.5 seconds is recommended as a starting point.

Whatever method of wiring is used, ensure that the external device is non-powered so that no damage is caused to the input channel. Refer to the RTU Instruction Manual for more information.

Velocity Calculations:

Plunger arrival velocity and duration are calculated when the plunger is sensed during an on cycle.

If the on cycle counts down with no arrival detected then a value of –1 is recorded for the velocity and duration.
If multiple velocity records are averaged for comparison with the target value then only values greater than zero are used.
The date and time of the plunger arrival are also recorded. The time is in the format HH:MM:SS and the date is in the format YYYY:MM:DD. The leading zero will not be present for the date and time data.

Ten records are kept for each of plunger velocity, duration, arrival time and arrival date. The oldest record is dropped from the list when a new record is added.

Leave the Plunger Sensor TLP undefined if no plunger is installed.

Appendix F – Continuous Critical Flow Calculation (Gray Equation)

Research has been done by various teams to develop a model for estimation of the critical velocity of a liquid droplet suspended in flowing gas.

A gas flow rate greater than the critical velocity will carry the liquid droplets up the tubing, whereas lower flow rates would result in liquid accumulation.

The model developed by Gray gives the critical velocity for water in ft/sec:

$$v_{min,\ water} = \frac{5.62\,(67 - 0.0031P_{wh})^{1/4}}{(0.0031P_{wh})^{1/2}}$$

The critical velocity for condensate in ft/sec is:

$$v_{min,\ condensate} = \frac{4.02\,(45 - 0.0031P_{wh})^{1/4}}{(0.0031P_{wh})^{1/2}}$$

Finally the gas critical flow rate in MMscf/D at standard conditions is:

$$Q_{gc,SC} = \frac{3.06\,P_{wh}\,A\,v_{min}}{T\,Z}$$

Where:

$v_{min,\ water}$ = critical velocity for water droplets
$v_{min,\ condensate}$ = critical velocity for condensate droplets
v_{min} = critical velocity for liquid mixture droplets
P_{wh} = flowing pressure at the wellhead
A = cross sectional area of tubing
T = gas flowing temperature
z = compressibility factor
$Q_{gc,SC}$ = critical flow rate

The user must enter the water fraction and tubing diameter. All other parameters are accessed from the AGA calculation and multivariable sensor.

Table 9 - Critical Flow Calculation Units

Parameter	Metric Unit	Imperial Unit
Water Fraction	-	-
Temperature	˚C	˚F
Pressure	kPa	psig
Tubing Diameter	mm	inch
Gas Critical Velocity	m/sec	ft/sec
Gas Critical Flow Rate	km^3/day	MMscf/day

Appendix G – ROCLINK 800 User Display File

FloBoss103_UserDisplay_Ver5.00.dsp

REFERENCE

[i] ROCLINK 800 Configuration Software User Manual (Emerson Form A6121)

[ii] Emerson ROC306/ROC312 REMOTE OPERATIONS CONTROLLER Instruction Manual (Emerson Form A4630)
Emerson ROC364 REMOTE OPERATIONS CONTROLLER Instruction Manual (Emerson Form A4193)
Emerson FloBoss 107 Flow Manager Instruction Manual (Emerson Form A6206)
Emerson FloBoss 103 Flow Manager Instruction Manual (Emerson Form A6114)
Emerson FloBoss 407 Flow Manager Instruction Manual (Emerson Form A6013)

[iii] ROC Protocol User Manual (Emerson Form A4199)

[iv] OAI Gas Well Production Optimization Program Register list (for Fisher RTU)